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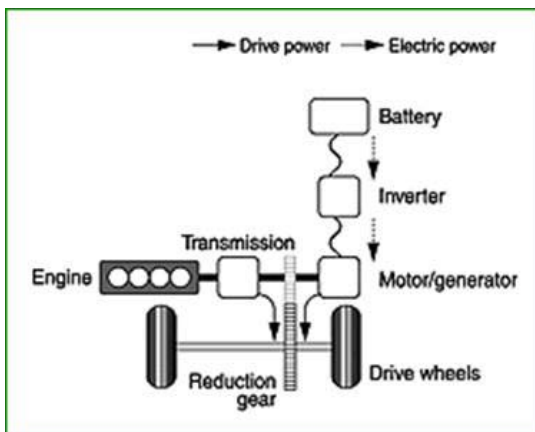
### **Parallel Hybrid Vehicles using Fuzzy Logic Control**

**Abstract:** A fuzzy logic controller for hybrid vehicles is proposed. A fuzzy logic controller is developed for hybrid vehicles with parallel configuration. Using the state of charge (SOC) of the energy storage, the driver command and the motor/generator speed, a set of rules have been developed. The fuzzy logic controller can determine the split between the electric motor and the internal combustion engine to achieve better fuel economy, low emission performance with out losing vehicle performance.

**Introduction:** Hybrid systems use a combination of an internal combustion engine (ICE), and an electric motor (EM). This combination has the potential of improving fuel economy by making use of regenerative braking on deceleration. There are three different types of hybrid systems:

- Series- The internal combustion engine (ICE) is used as a generator; providing electrical power to the electric motor (EM) and the battery.
- Parallel- The electric motor (EM) supplements torque to the internal combustion engine (ICE) which are both connected to the drive train.
- Series-Parallel is a combination of the two configurations.

In parallel configuration, the internal combustion engine (ICE) is connected to the drive train,



and the electric motor by the mechanical torque/speed coupler, and the battery is also connected to the electric motor. There are five different ways to operate the system:

- 1) Provide power to the wheels using the EM only

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- 2) By using the ICE only
- 3) Both the ICE and the EM simultaneously
- 4) Charge the battery using the ICE power to drive the EM as a generator
- 5) Slow down the vehicle by letting the wheels drive the EM as a generator that provides power to the battery (regenerative braking)

In order to manage the flow of energy between all components, a power controller is required to take into account the energy available in the battery.

**Energy Management Strategy:**

The goal is to increase fuel economy, and to reduce emissions without sacrificing the performance, safety and reliability of the vehicle. In order to achieve these goals, it is very important to optimize the architecture and components of the hybrid vehicle. The energy management strategy used is just as important as the architecture and components. A power controller is used to control the energy flow between all components and optimizes power generation and conversion in the individual components. The energy in the system should be managed as follows:

- 1) The driver input (from brake and accelerating pedals) are satisfied consistently
- 2) Battery has full charge at all times
- 3) All four components: ICE, EM, battery, and transmission should have an optimized overall system efficiency

During the operation of the parallel hybrid vehicle, the power controller should determine how much power is needed to drive the wheels based on the driver input and how much is needed to charge the battery. Then the power controller should split the power between the ICE and the EM. If the battery is low on charge, the controller will assign negative power to the EM. Meanwhile the ICE will provide the power for both driving the wheels and charging the battery.

### **Power Split Strategy:**

The difference between using the ICE or the EM to drive the wheels is as follows:

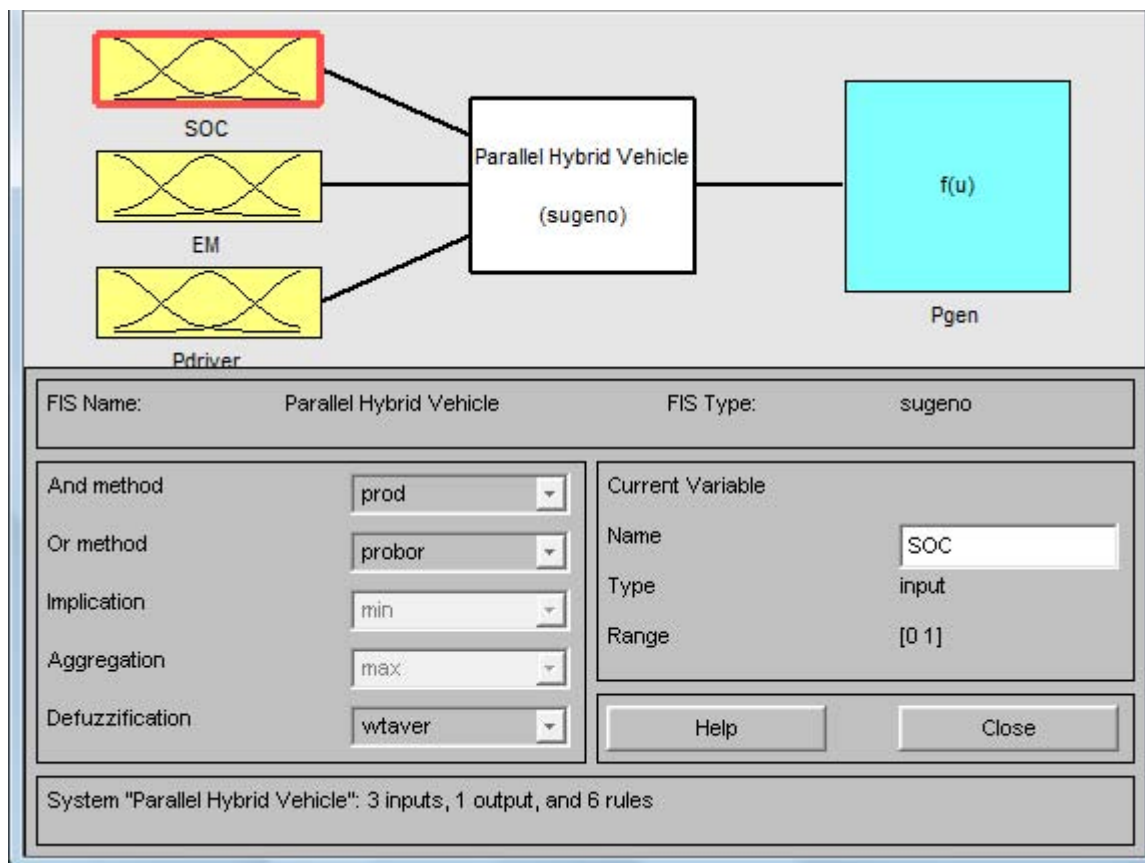
When the ICE is used, the energy flows directly from the ICE through the transmission to the wheels that means the mechanical power produced will promptly be used to drive the wheels. When the EM is used, energy first flows from the ICE through the transmission to the EM, operated as a generator, to charge the battery; then the energy will flow from the battery to the EM, operated as motor, to the wheels, that means the same mechanical has been converted to electric power, and then back to mechanical.

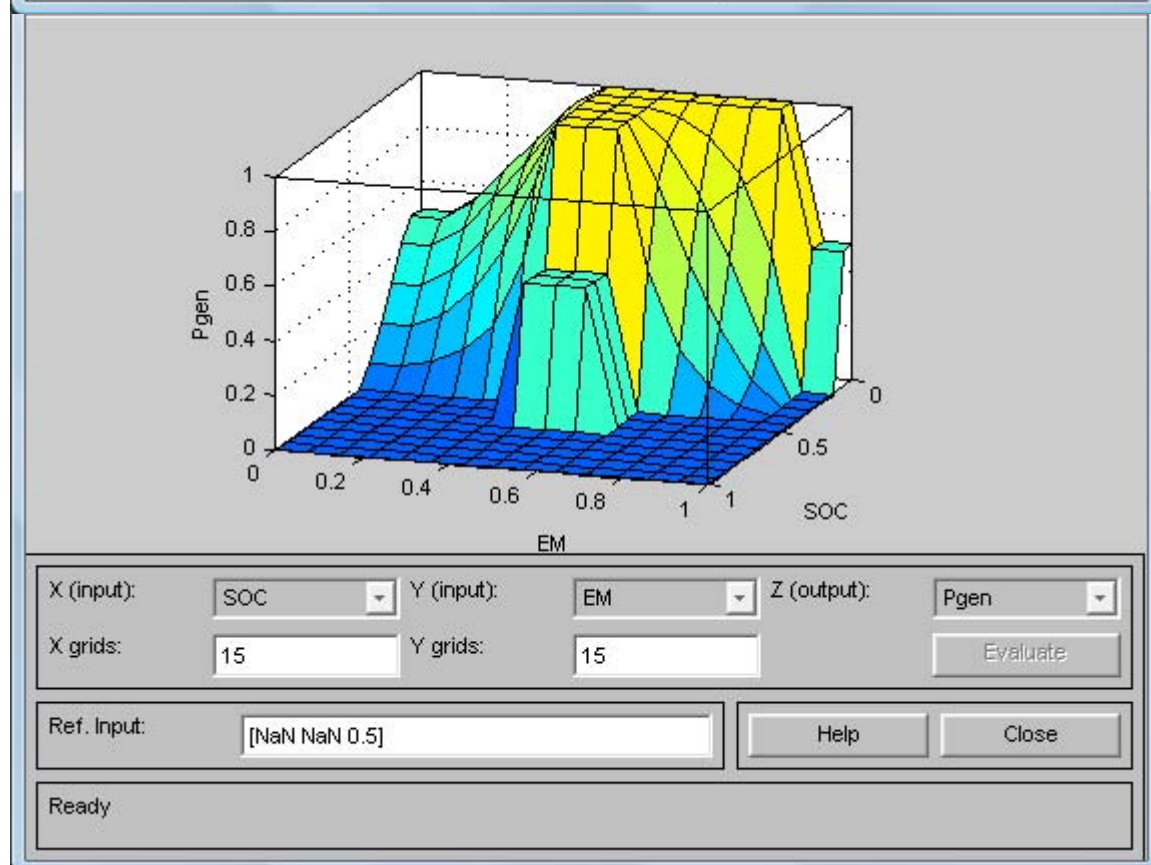
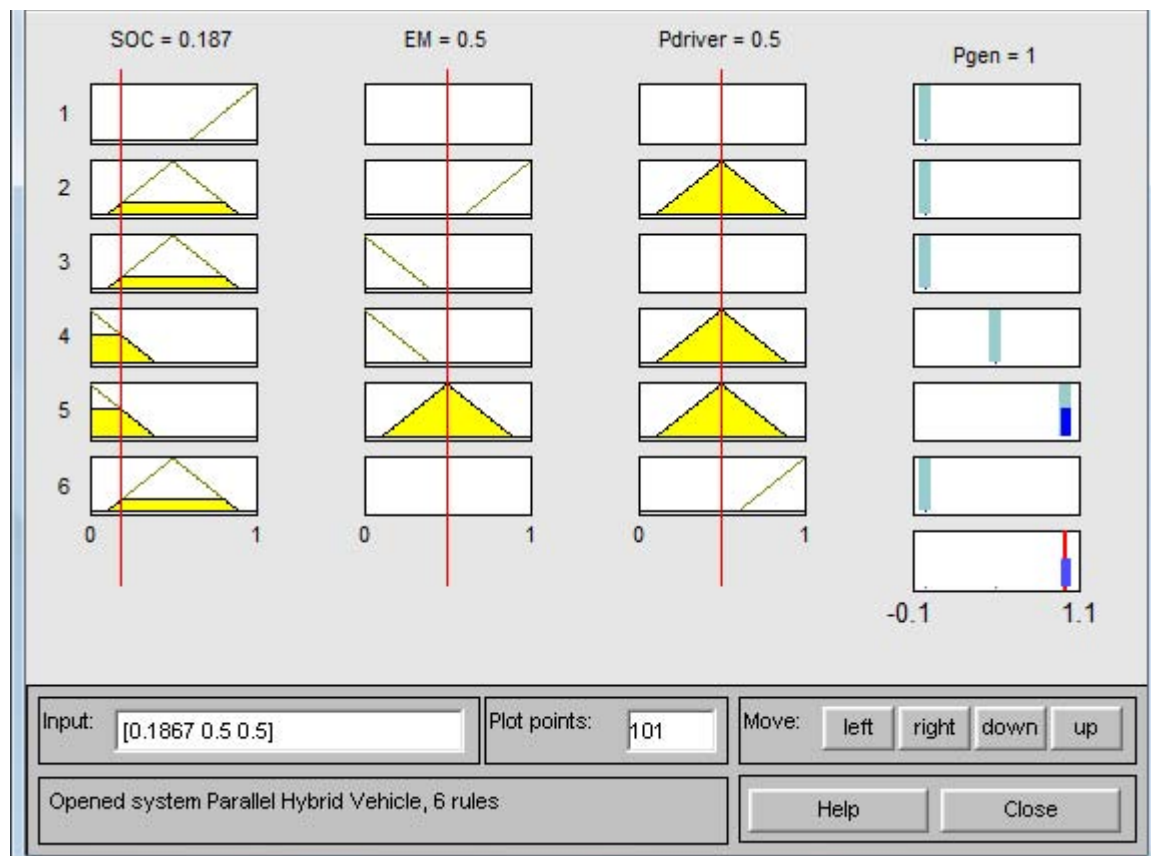
### **Fuzzy Logic Control Basics:**

The Table below presents a list of if-then rules; the first part of a rule (preceding “then”), called the afterwards, specifies the condition (i.e. the combination of inputs) for which the rule holds. The second part (following “then”), called the effect, is the corresponding control action, i.e. the controller output. The variables in the Table below, preceding “then”: SOC,  $P_{\text{driver}}$ , and  $w_{\text{EM}}$ , correspond to the inputs of the FLC: Battery state of charge, driver power command, and EM speed respectively. The variable following the “then”:  $P_{\text{gen}}$  (Generator power), and scaling factor correspond to the output.

### **The following is the Rule of the fuzzy logic controller table:**

- 1.) **If** State of Charge (SOC) is too high **then**  $p_{\text{gen}}$  is 0 kW
- 2.) **If** SOC is normal **and**  $p_{\text{driver}}$  is normal **and**  $w_{\text{EM}}$  is optimal **then**  $P_{\text{gen}}$  is 10kW
- 3.) **If** SOC is normal **and**  $w_{\text{EM}}$  is not optimal **then**  $P_{\text{gen}}$  is 0kW
- 4.) **If** SOC is low **and**  $P_{\text{driver}}$  is normal **and**  $w_{\text{EM}}$  is low **then**  $P_{\text{gen}}$  is 5 kW
- 5.) **If** SOC is low **and**  $P_{\text{driver}}$  is normal **and**  $w_{\text{EM}}$  is not low **then**  $P_{\text{gen}}$  is 15kW
- 6.) **If** SOC is **not** too low **and**  $P_{\text{driver}}$  is high **then**  $P_{\text{gen}}$  is 0kW





**Conclusion:**

In this paper the fuzzy logic controller for the parallel hybrid vehicle was presented. The power controller optimizes the energy flow between the components of the parallel hybrid vehicle, and the energy generation, and conversion in the components (ICE, EM, Battery, and transmission). The accelerator and the brake pedal inputs of the driver power command will be converted by the power controller. The fuzzy logic controller will compute the optimal generated power by using the, driver power command, state of charge battery, and the EM speed, which they are also used to compute the optimal ICE, and EM power. The driver inputs( from braking, and accelerating ) are satisfied consistently by the power controller., to insure the battery is charged all the time, and the fuel economy of the vehicle is the best.